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APPROPRIATE TECHNOLOGY

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PREFACE

Social and technical innovations are crucial to solving or alleviating many important contemporary problems; for example improvement of living and working conditions in the developing countries. In this paper we try to explore some problems of technological change. The main ideas contained in this paper are the result of discussions among the three authors, who have very different social backgrounds and viewpoints.

Most of the ideas in the paper were presented at the IFAC-Symposium "Criteria for Selecting Appropriate Technologies Under Different Cultural, Technical and Social Conditions", (Bari, Italy, 21-23 May 1979). The discussions at this meeting and at other scientific meetings, especially those at IIASA, the East-West Center Honolulu, and at the Institute for Developing Countries, in Berlin, German Democratic Republic, stimulated our thinking about appropriate technology.

We especially have to thank for their comments Umberto Pelligrini (Italy), John Rijnsdorp (The Netherlands), Peter Stier (GDR), John Brownell (US), Kathleen Wilson (US), Walter Goldberg (FRG), Rolfe Tomlinson (IIASA) and Wolfgang Sassin (IIASA).

APPROPRIATE TECHNOLOGY

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Economic modernization is a central concern of most developing countries. The critical situation in most of these countries--hunger, illiteracy, disintegration of traditional cultural and social structures--leaves no alternative but the social, economic, technological modernization. Of course technological modernization will not automatically solve the problems faced by these countries; indeed inappropriate technological strategies may create more problems than they solve. The problem is, what kind of technology is needed to cope with the present situation in these countries?

Technological modernization is an important precondition for the improvement and evaluation of national economies which should be able to supply the population with food, homes, employment, education possibilities, health care, and fields of cultural activity. This is an important precondition to participation in the international division of labor and cultural and scientific-technological progress of mankind.

To propose that these countries should hold their technology, economy, society and culture at their present stage or initiate the technology to serve traditional values, is an irresponsible underestimation of their real problems. Preservation of the status quo is out of the question, and attempting to preserve the status quo will incur great human suffering. The need for technological, organizational and social innovation both in the developed and in the developing countries is too great.

Social, organizational and technical innovations are different parts of a joint system (Figure 1). Without technological change it is impossible to alter the organizational and social system. On the other hand, technological innovations without organizational and social innovations will not improve the living conditions of the population or secure the development of an independent national economy.

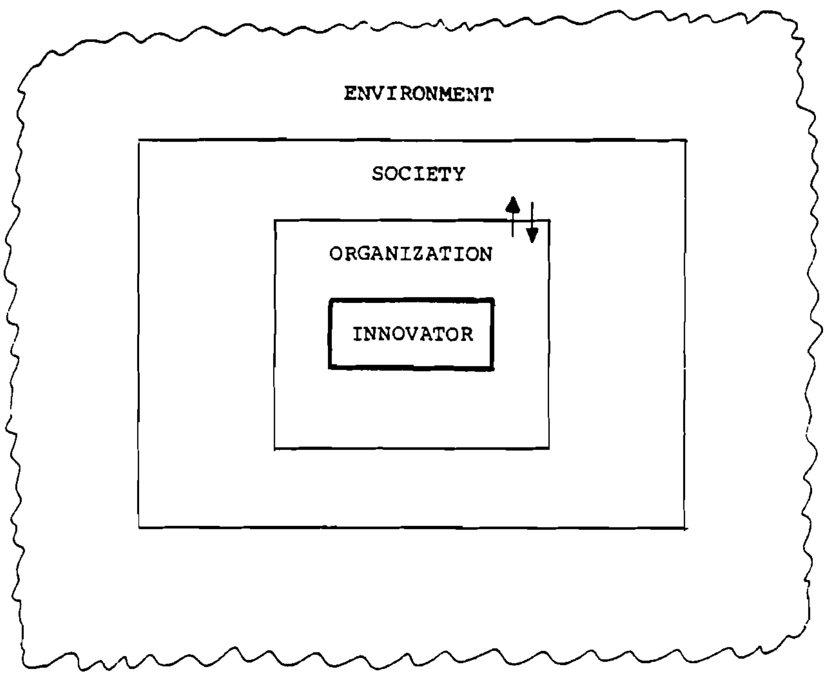

Figure 1. The innovation process in a hierarchical context.

The need to consider both the social and technical sides of the innovation process has important consequences for the approach we use to identify appropriate technologies for the developing countries. In this connection two kinds of approach are possible. On the one hand, we can start from single technological change and look at its social consequences and implications or at the governmental measures needed to ensure its efficiency. This is, for example, the main aim of technology assessment. On the other hand, we can go out from social needs and goals, from existing and forthcoming leaks or bottlenecks in resource processing systems and then look at the given field of technological possibilities for a technological fix. We could call this latter approach socio-economic opportunity analysis - SOA.(Figure 2).

Both approaches are important for developing countries. Ideally the two will be used in a complementary fashion in formulating policy aimed at improving the technical basis in the developing countries. SOA is especially important in orienting the national technology policy (Figure 3).

The importance of second approach SOA can be realized by looking at the nature of the innovation process. Innovations are the units of technological change. A technical innovation is a complex activity which proceeds from the conception of a new idea to a solution of the problem and then to the actual utilization of the new item of economic or social value. The pace of technological change has made innovation a key concept in today's world. Social, economic and technological innovations are essential for survival in a world with resource shortages, hunger, illiteracy, wastage of human capabilities and great imbalances between the different parts of the world.

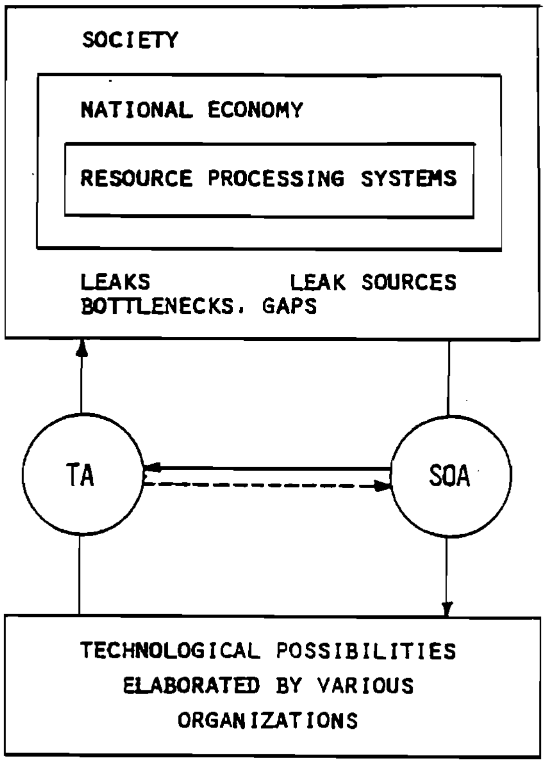

Figure 2. The role of TA and SOA.

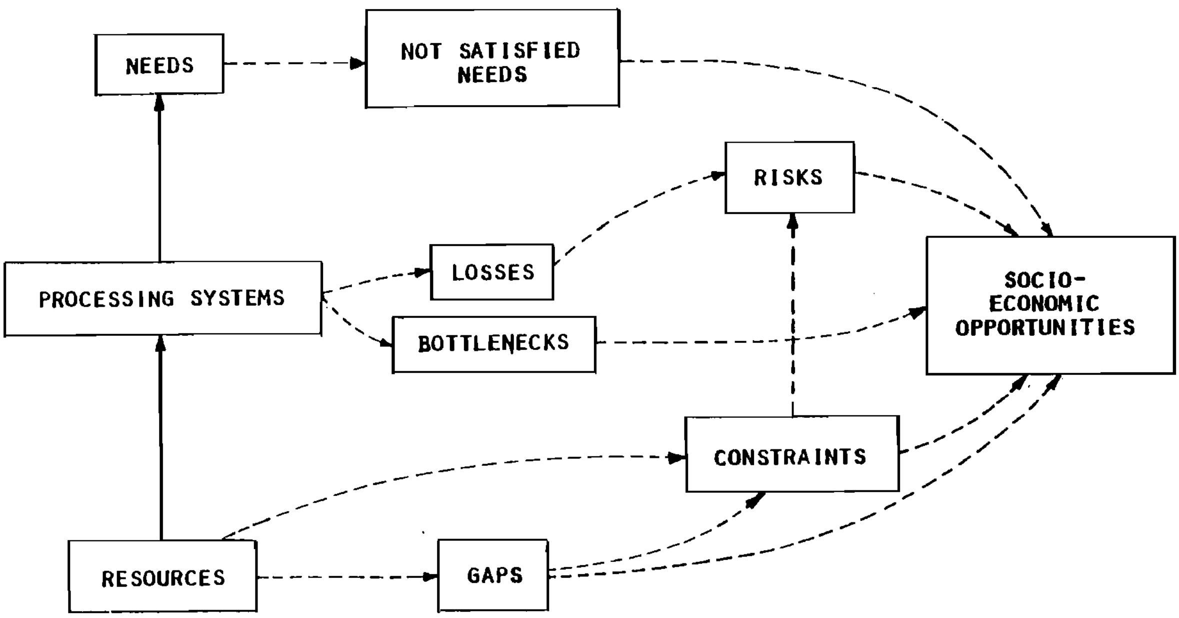

Figure 3. SOA in the context of national problems.

Generally speaking, innovation comes about through the fusion of a recognized demand and a recognized technical feasibility into a design concept. This is truly a creative act in which the association of both elements is essential. If a technical advance alone is considered, it may or may not result in a solution for which there will be a demand. Similarly, search for a response to a recognized demand may or may not result in a solution, depending on the technical feasibility in the current state of technical knowledge (Figure 4). One of the clearest and most common findings from different case studies on innovation is the domination of demand factors. For example, in the study entitled "Successful Industrial Innovations" conducted by S. Myers and D.G. Marquis, under sponsorship from the U.S. National Science Foundation, it was found that technical factors accounted for only 21% of the innovations study, and demand factors, market and production factors accounted for 75% of the innovations.

The conclusion of this story is: technical appropriateness is insufficient. In planning for socially adaptive technical change one must also recognize and respond to current and future national demands; one must strive to develop from the body of international technical knowledge a national technical potential in the country that will be able to respond to demand.

Currently, most developing countries are unable to do either. They generally lack the ability to articulate their real demands from the point of view of gaining national goals. Their internal market is dominated by external forces and goals. Moreover they are unable to create an indigenous basis for technological development and improvement, because currently the forces which work against this are too strong. We will only mention here the brain drain and patent policy.

The gap in the capability of the developing countries to articulate their indigenous demand for innovations and the lack of technological knowledge results in a difficult situation.

The present level of technology in the developing regions is shown in Table 1. We know that the energy consumption per capita is an important indicator not only of living standards, but also of the technological level. The distribution of energy use is presently very unequal, region I (North America - United States and Canada) with 6% of the world population consumes 32.2% of the world energy production. Region V with 38% of the world population consumes only 4.1% of world energy production. Therefore the per capita energy consumption is 52 times higher in region I than in region V.

All this indicates that the raising of the technological level in the developing countries is a global problem and is crucial for the future of mankind. This is the great challenge of our time, and to the coming generations.

At present developing country technologies are not only characterized by their low average levels but also by great disproportionalities in internal technological development.

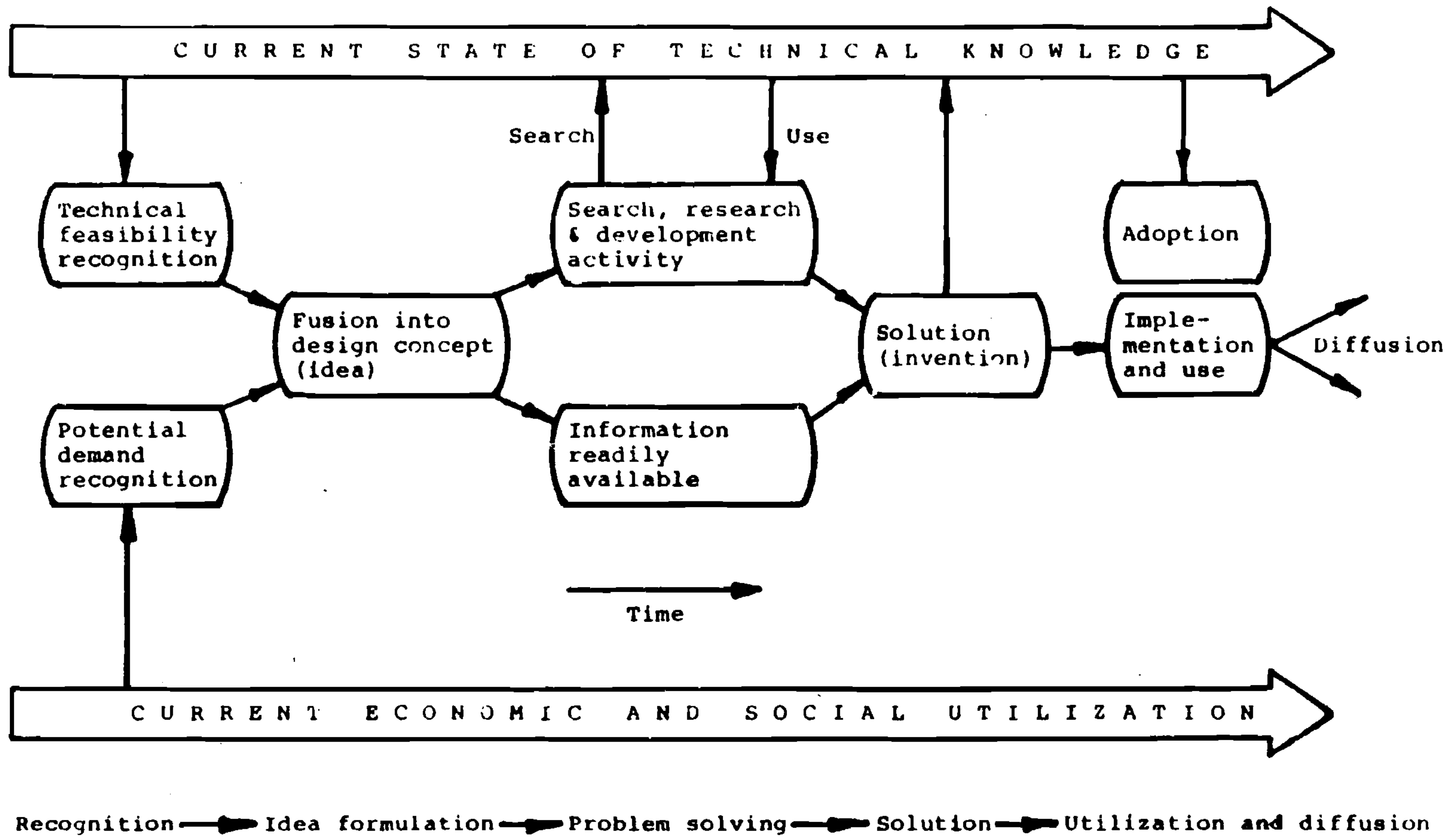

Figure 4.

Source: Myers, J. and D.G. Marquis, Successful Industrial Innovation, National Science Foundation, NSF-69-77. J.32.

Table 1. Share of different socio-economic system surface, population raw material production, industrial production, R & D personnel, and patents in percent.

	Surface 1977[1]	Population 1977[1]	Raw Material 1970[2]	Industrial production 1975[3]	Scholars & Engineers 1970-3[4]	Patent Notification 1974	Patent Notification abroad 1974
Socialist countries	26	33	28	40	49	30	3.5
Comecon countries	18	9	--	35	--	--	--
Developing countries	49	48	27	10	6	2	0.5
Developed market economies	25	20	45	50	45	68	96

[1]Statistiches Jahrbuch der DDR 1978, p.29.

[2]Sprote, W., Thole, G. Internationale Wirtschaftsbeziehungen und Entwicklungslander, Staatsverlag Berlin 1978, p.24.

[3]Kuczynski, J., Die Krise der kapitalistischen Weltwirtschaft, Dietz Verlag Berlin 1976, p.10.

[4]East-West Technological Co-operation, Brussels 1976, p.207.

Sophisticated firms and producers, often foreign owned, are islands in an ocean of preindustrial production. These sophisticated parts of the national economy are not integrated into the national division of labor, but are isolated groups, more closely linked to foreign than national control. The production of the modern sectors in developing countries tends to be oriented toward the demands and needs of the developed country populations and the affluent minority in the developing economies. Standing apart as they do, the sophisticated sectors of developing economies often play a disruptive role in the national economy. They not only fail to accelerate economic development they also often tend to destroy the traditional technological basis without creating a new technological basis able to meet national needs in the medium and long-term perspective. The concept of "dual economy" is a reflection of--and to some extent an apology for--this situation, but it is not able to show the way for the establishment of an integrated national technical basis, with a productive relationship of the different technological levels.

Table 2 shows us the different technological levels which exist in each country. In all countries lower level systems a to c exist side by side. But in the industrialized countries the production volume of a and b technology is very low and the

Table 2. Levels of technology.

Level	Content	Example
A. Technology	Manual drive, task execution, control and logical functions	1. Drop spindle 2. Spinning wheel 3. Improved spinning wheel
B. Technology	Substitution of mechanical for human energy (power tools)	Spinning wheels with external drive power
C. Technology	Substitution of the mechanical for human energy and task execution	1. Selfactor 2. Ring machine 3. Open-end spinning
D. Technology	Complete substitution of mechanical-technical for human operation, including control and logical functions	1. First generation automated equipment 2. Second generation automated equipment

different technological levels function as parts of an integrated national economy. The concept of intermediate technology is largely oriented towards furthering semi-mechanized technologies (class b), but this cannot help us meet the objectives of the developing countries to increase their standards of living. It is also not possible to jump from technology level b to d. In most cases the developing countries have not enough investment, skilled workers, and infrastructure to use the d technology. This technology is also not appropriate for creating a national technical basis capable of producing enough goods for the population and for securing employment. The developing countries are faced with the problem of allocating their limited resources and investment between the different levels of technology in a way that optimizes their utilization of domestic natural and human resources for producing the stream of goods and services needed to meet the demands of their populations. Therefore one cannot say what is the appropriate technology from the standpoint of a single company, branch, or territory--one must look at the economy as a whole and resource situation and accumulation potential. This is the reason why the prevailing approach, one in which one only looks to the features of a single technology or to technologies of a specific technological level, is inadequate. The developing countries need an efficient mixture between the different types and levels of a technology. True, there currently seems to be a deficiency of technologies which utilize natural and human resources of the developing countries. What are often referred to as "soft", small scale and low capital technologies, which make extensive use of local labor and raw materials. These kinds of technology are important in the present stage of development and it is necessary to put greater attention to developing such kinds of technology. But this could only be a part of the technical basis of a country.

The small-scale sugar plants developed in India and which now account for more than 20% of the country's production, are a good case in point (Garg 1976). The average investment per ton of output is two and a half times smaller than in the large modern plants, and the investment per worker, nine times lower. Differences in production costs however are much smaller (less than 20%), and the present balance in favour of the small-scale technology could easily be tilted. This in fact is what happened with a rather similar type of technology in Ghana. Analyses made in 1969 showed that the small-scale, low-cost sugar technology was more attractive from an economic point of view, but for years later, with the rise in wages and the improvements in modern large-scale plants, the situation was completely reversed. Economics can, of course, also operate in favour of the small-scale low-cost technology. In India for instance, the sudden rise in the price of imported oil has helped to make cow dung much more attractive as a fuel. However important such kinds of technology might be, we must not foster the illusion that it is possible to use only this kind of technology to solve the problems of the developing countries. "Appropriate technology" is not a synonym for soft technology. The problem is to make such kinds of technologies into an integrated part of the national technological basis. Both extreme approaches of "small is beautiful" and "big is wonderful" are not appropriate. The technical basis must include hard and soft, large and small, high and low technologies in appropriate proportions in order to be able to improve the economic efficiency of the countries and help them use the benefits of the international division of labour.

Unless integrated into a mixture of different types and levels of technology in a concept of the development of national technology basis, low cost labour intensive technologies would only be another term for low labour productivity and low standards of living. This would mean recommending underdeveloped technologies to underdeveloped countries.

Table 3 shows the impacts of different technological levels on the satisfaction of national needs in the developing countries. The results of our evaluation are the following:

1. Governmental technology should try to find the right mixture between technologies a, b, c, and d.

2. Technologies b1, c1, and c2 must have a dominating role. This results from the benefits and criteria of expenditure.

3. We see also that it is necessary to strengthen the capabilities of developing countries to go from technology a and b to c3 and d1 and to develop technology from level c and d, which are particularly important for the developing countries.

Table 3. Impact of Different Technology Levels on the National Economy of Developing Countries.

Criteria	Levels of Technology								
	a1	a2	a3	b1	c1	c2	c3	d1	d2
Effects on Growth of Production	0	1	2	2	2	3	3	3	3
Better Satisfaction of Basic Income Needs	0	0	1	1	2	3	3	4	4
Employment Effect Capital Growth Savings	3	3	3	3	3	2	1	0	0
Effect on Labor Skills	0	0	0	1	2	2	3	4	4
Impact on National Division of Labor	0	0	0	1	3	3	4	4	4
Use of National Resources	4	4	4	3	3	3	2	1	1
Integration in National Market	4	4	4	4	3	3	2	1	1
Accommodation on National Condition	4	4	4	4	2	2	1	0	0
Linkage to International Developments	0	0	0	0	1	2	3	4	4
Sum of Benefits	15	16	17	19	21	23	22	21	21

Expenditure Criteria	Levels of Technology								
	a1	a2	a3	b1	c1	c2	c3	d1	d2
R&D Intensity	0	0	1	1	2	2	3	4	4
Demand to the Infrastructure	0	0	0	1	2	2	3	4	4
Optimum Production Scale	0	0	0	0	1	2	3	4	4
Import Share	0	0	0	1	2	3	4	4	4
Sum of Expenditure Criteria	0	0	1	3	7	9	13	16	16

Evaluation:
0 without importance
1 little importance
2 medium importance
3 high importance
4 very high importance

A good example of this is the solar pump developed by a European firm in cooperation with the University of Dakar, which is currently being introduced on a large scale in Mexico. It uses a widely available source of energy--the sun, to provide villagers with a scarce but vitally important resource--water. Although it is technically very sophisticated, it requires virtually no maintenance and seems to have potentially a very long life.

Successful establishment of an integrated national technical basis in the developing countries requires that governmental technology policy play a key role. Governments' main goals should be the following:

1. Creation of domestic complexes focusing on national basic industry, mechanical engineering, consumer goods and export industry.

2. Development of domestic agriculture to form the resource foundation for the accumulation of means and manpower for domestic industry. This makes the success of technical innovation very strongly dependent upon social innovation, including real agricultural reform and the development of agricultural cooperations. We must also bear in mind that for a long period in the developing countries, agriculture will be the basis for development of industry. Not only from the standpoint of food and raw material supply, but also from the standpoint of manpower and financial sources for investment. Only on an advanced level will it be possible to change this and agriculture can then be developed on the basis of industry. Also in the present stage it will be necessary to make a serious commitment to use industrial processes to improve agricultural efficiency.

3. To make maximum efforts to use the domestic natural and human resources.

4. To develop self-reliance in the mechanical engineering industry and equipment production.

5. To extend and improve the domestic division of labor.

6. To maintain a mutually reinforcing relationship between traditional sectors which will benefit from modernization and modern sectors, which will need to draw labor and other inputs from traditional sectors.

7. To establish and maintain a close relationship between social innovation and technical innovations.

8. To lay a solid domestic scientific-technical foundation capable both of serving the national needs and of holding trained manpower, i.e., stopping the brain drain.

9. To facilitate selective transfer of technology from the developed countries in a way that will help to improve the national capability to use international know-how without sacrifices of national independence.

10. To secure a high level of technological unification and standardization.

11. To establish a national system of management and planning of science and technology.

In searching for appropriate technology, one must always keep in mind the problems of employment and resources. In the next twenty years the developing countries will need more than 300 million additional jobs. Assuming that each working place costs 10,000 dollars (in the U.S. 20,000 dollars), then 150 billion (10^9) dollars per year will be required to secure enough working places in the developing countries. 150 billion dollars is a lot of money, but then again, it is only half the annual world expenditure for armaments (350 billion dollars in 1978).

Many of us have the impression that only the developed countries have resource problems. This is false, the resource situation in the developing countries is much worse than that of the developed countries. Many of them not only lack natural resources, but they also lack the technological means to efficiently utilize the resources which they do have. Moreover they are also unable to substitute new artificial resources for scarce natural resources. This situation is exemplified by one of the most constraining resources, energy.

One of the important findings of the Energy Project at IIASA conducted by Prof. Wolf Häfele (1979) is that the 1975 world average primary energy consumption was about 2.1 kilowatt years per capita, per year, but 70% of the world population lives at less than average consumption levels, and a depressingly large share at only 0.2 kwy/cap. This corresponds with the great differences in per capita GDP. Any improvement in this situation needs the better use and extension of energy production. But traditional resources--oil, coal, and gas--will in neither case be able to satisfy more than 65% of energy demand in 2030. The remaining 35% will have to come from new resources like nuclear power, soft and hard solar energy, coal liquefication, etc. The great danger for the developing countries is that they will be neither able to pay the higher prices for traditional energy resources such as oil, gas and coal, nor to substitute new synethetic energy resources for scarce resources.

It poses a great challenge to the developing country to develop their own scientific and technical basis and to take part in world-wide scientific-technological progress. The developing countries can only avoid deterioration of their present condition by establishing their own national systems of division of labor, organized to help them use their own resources to gain equal rights in the international division of labor.

The main concern at present of government technology policy must be the stimulation of flow of labor from a and b technologies (small scale production on a manual basis), to the c and d technologies (large scale production on a technologically advanced basis). The a and b technologies must be strongly coupled to the c and d technologies. Conservation of the "dual economy" in the developing countries will not help them solve their problems. Means of attaining integrated development include the following:

1. For domestic industry (on the c and d technology level) to develop and produce appropriate technology and equipment for a and b sectors of national economy.

2. Social innovations for new organizational forms of small scale production and productive cooperation between social scale production units and large scale factories.

3. Development of education system and elimination of illiteracy. Generally educational systems need to be made more production oriented. Such educational innovation is crucial, because the old educational systems, whose main aim was conservation of the traditional social structures are to a large extent consumption oriented and incapable of preparing the new generation to cope with the problems resulting from the process of industrialization and from global development.

4. To support the small scale, labor intensive, export oriented sectors and to stimulate selective export lines based on large scale production.

5. To establish technological consulting points and service feasibilities (especially for agriculture and handicrafts).

6. To step up the R & D expenditure for the technological development of small scale industry.

7. To promote stimulation measures for the technical development of final scale industry through brokerages, credit, guaranteed markets, etc.

These measures aim to integrate small scale production into the national socio-economic and technological basis. Only through integrated development can national natural and human resources be effectively employed to attain the economic growth needed to meet the needs of the population.

Developing country planners must seek a combination of different technological levels which will lead to well proportioned development of the technical basis. This combination could have the following features:

1. Use of surplus manpower for the production of labor intensive production means.

2. Concentration on the import of advanced technology (level c and d) on key operations of the core processes. The other processes should be based on labor intensive technologies.

3. Use of the limited stock of advanced equipment for demonstration and education.

4. Transposition of old production means to small scale firms.

5. Promotion of high standards of quality strategy in means of production.

6. Establishment of a closed technological cycle from raw materials to final products on the basis of national division of labor.

7. Avoidance of nonintegrated investments and technological conservatism.

Table 4 shows an example of the possible combination of different technologies. This indicates the necessary direction of technology transfer which could help the developing countries cope with their problems. This technology transfer includes:

-- hardware supply (equipment),

-- installation and operation of new technology (software),

-- organization for efficient management of technology (orgware).

The transfer of hardware is much easier than transfer of software and orgware, which is socially and culturally specific, and often cannot be made without social, economic and cultural changes. The extent of changes in the system of cultural and social values depends on the strength of the social forces which affect it. The developing countries presently pay dearly for technology transfer (more than 15% of the net proceeds from exports), but the results of this transfer have not helped to solve the serious problems of these countries. Reasons vary--the most important are the social forms in which this transfer is taking place, the inappropriate character of the transferred technology, and social conditions in some of the developing countries which make them unable to absorb new technologies. Two key measures for the better use of technology transfer for national needs include:

1. Insurance that the transferred technology can be integrated into the national system of division of labor;

2. Creation of a scientific-technical basis which can effectively absorb the transferred technology.

Table 5 shows a rough approximation of the magnitude of the effects of different forms of technology transfer. Note that the contribution of the forms of division of labor increases geometrically as one moves from left to right (from non-integrated use of raw materials to full integration into the national economy and export sectors) while the influence of appropriateness of technology increases linearly from top to bottom as one progresses from conventional to highly appropriate technologies. The matrix entries are the sum of the row and the column values.

Table 4. Variants of technological basis of a production process with high acceleration effect and high employment effect.

Level	Example	Technology level of core of the main process	Technology level of the auxiliary and side process of pre- and incremental operations of the main process	Supply of equipment produced with technologies on the level			
				A	B	C	D
I	Synthetic production	C,D	B		X	X	X
II	Synthetic thread manufacture	C	A	X	X		
III	Weaving of synthetic cloth	C	A	X	X		
IV	Weaving of improved synthetic cloth	C	A	X	X		
V	Sewing	A	A	X			

Table 5. Stages of technology transfer and its evaluation (Numbers designate approximate magnitude of the effects of various forms of technology transfer)

Rate of suitability \ Impact of the national division of labor	Without integration of national system of labor division--only using		Part integration in the national system of labor division	Integration in the national labor division including export
	raw material	manpower		
	1. (1)	2. (2)	3. (4)	4. (8)
1. Transfer of conventional technology (0)	1	2	4	8
2. Transfer of partially appropriate technology (1)	2	3	5	9
3. Transfer of highly appropriate technology (2)	3	4	6	10

To illustrate the table's meaning, a foreign owned and operated mining enterprise using foreign labor would fall in the upper left hand corner (a_{11}) of the matrix and would have an influence of 1 on a scale from 1 to 10. A domestically owned enterprise, using domestic labor and inputs from other domestically operated enterprises and selling its products both on domestic and export markets, and using technologies well adapted to local circumstances would fall in the lower right category (a_{34}) and have an impact value of 10.

There are different ways of technological development in the developing countries. In Table 6 we try to evaluate them with respect to developing country objectives. We need the right mixture between these different means of technological change. The most favoured means (capital export through multinational companies) cannot solve the problems of these countries because it does not help to develop the technical capabilities of these countries. The other ways are more difficult, but they can help to develop technological self-reliance. In this connection the governmental technology policy has to play a great role in

-- national planning

-- resource allocation

-- evaluation

-- financial support

-- sales promotion

-- export promotion

-- subvention.

Tools for Analysis: Can Models Help?

Mathematical modeling becomes useful only when one has a hypothesis about a system that can be formulated in precise mathematical terms. Once a hypothesis can be stated mathematically, a model can assist one in deducing implications of one's hypotheses that would not be apparent using verbal reasoning.

Where can models assist in thinking about appropriate technology? The key concept in the previous paragraph, the one that immediately delimits the role of modeling, is the distinction between deductive and inductive reasoning. Models and computers are wonderful devices for deductive calculations much superior to the human brain. However, when it comes time for induction, the tables are turned; any intelligent human being can run circles around almost any computer. Models can explore a hypothesis, once it is formulated, but they cannot formulate the hypothesis.

Table 6. Different Ways of Technological Innovations and its Preconditions in Developing Countries

Necessary Preconditions	Sources of Technological Innovations: 1. Foreign Investments	2. Input of Foreign Technology for National and Private Firms	3. Import of Appropriate Technology for National Private Firms	4. Import of Technology for Nationalized Firms and Governmental Development Programs	5. National Technology Development in Firms	6. National Technology Development in the Framework of National Programs	7. National Technology Development in the Framework of International Cooperation and National Programs
(1) Qualification of Labor Force	0	2	2	3	4	4	4
(2) National R&D Potential	0	1	1	3	4	4	4
(3) National Management	0	2	2	3	4	4	4
(4) National Market	1	3	3	4	4	4	4
(5) National Information System	0	2	2	3	4	4	4
(6) National Experimental Basis	0	2	2	3	4	4	4
(7) National Mechanical Engineering	0	0	1	3	4	4	4
(8) Mental Motivation	1	3	3	4	4	4	4
(9) Material Interest	3	3	3	4	4	4	4
(10) Infra-structure	1	2	2	3	3	3	4
(11) Integration in the Nationai Division of Labor	0	2	2	3	3	4	4
(12) Integration in International Division of Labor	4	2	3	3	2	3	4
(13) Sum	10	24	26	39	44	46	48

Evaluation: 0 without importance; 1 little importance; 2 medium importance; 3 high importance; 4 very high importance

Earlier we described two approaches for identifying appropriate technologies--through tracing the socio-economic ramifications of a single technological change (technology assessment or TA) and through starting from observation of social needs and problems and looking for a technological fix (socio-economic opportunity analysis or SOA).

Clearly, most of the work in these two approaches is inductive and will be better handled by natural than by artificial intelligences. Technology assessment requires sorting through all dimensions of society, including sociological, environmental, micro and macro economic, geographic and political dimensions, and attempting to ascertain how and where the influences of a new technology are likely to be felt. Modeling has not progressed to the point where it can sensibly link all these dimensions of society into a single model, and it may never progress that far. Sometimes existing models of systems of complex interrelationships exist--for example, economic input-output models--can be adapted to examine the effects of a technological shift on the sub-system of society they characterize--provided that the attributes of the shift can be described in a format compatible with the model's structure. However, this exercise is costly and laborious, and to the extent that it draws attention away from the features of society not included in the model and focuses it on the modeled aspects, it will create a distorted image of the effects of the technological shift. A nation would be ill advised to devote more than a few percent of its budget for technological planning toward such efforts or to place much emphasis on its findings.

The barriers to using models in socio-economic opportunity assessment are similar to those in technology assessment. SOA is largely a matter of matching a broad and flexible conception of the potentials of technology to an equally broad and flexible conception of social needs, problems and opportunities. The intelligence required is creative and intuitive. The work is more a matter of craftsmanship than of science--it requires the craftsman's sense of the potentials of tools and materials and the designer's sense of balance, form, and function.

True, in SOA models may serve to point out forthcoming social needs. For example, an energy model may give clues to forthcoming difficulties meeting energy needs or an economic model may suggest problems associated with sluggish growth or with balances of payment. However, because the whole of society cannot be modeled, models can only be one of the many sources suggesting social problems--and once again, concentrating on the portion of society that has been modeled will tend to create a distorted image of social problems. On the whole, the central and critical parts of SOA are beyond machine intelligence.

There are however, other places where models can be used. Once an appropriate technology has been identified, for example, the problems become much more amenable to precise definition and the balance between inductive and deductive reasoning requirements shifts. The tactical questions of implementing an appropriate technology--the concrete pragmatic realities of investment, marketing, and so forth--can be precisely formulated. Here models can play an important role. Strategy without tactics will never work. No matter what technological innovation strategy a developing nation adopts, if it turns out that new enterprises cannot bear the start-up costs of technological shifts, or that there are no customers for the innovator's products, the strategy will fail. Such failures are costly for the developing countries.

Failures due to inability to meet start-up costs are particularly problematic to developing self-reliance. Say it takes six or eight years of operation before a new technical system attains the efficiency needed to be profitable, a common situation for a c or d type technology starting up in a developing nation. While few domestic entrepreneurs will have the massed reserves to survive six cumulative years of financial loss, it is child's play for a multinational corporation. Furthermore, through its past experiences in setting up new enterprises, a multinational corporation may be able to show profits faster, with fewer costly mistakes than an inexperienced local producer. Without policy intervention, such a situation will automatically tend toward foreign-dominated control of advanced technological processes in the developing nations.

But say government does intervene, either by underwriting private industry or by beginning state-controlled new enterprises; what happens if the domestically produced product turns out, after the period of protection, to be unsuited to the market? What if consumers like the traditional product, or an imported brand more than the product of the government supported or controlled industry? Does the government then proceed to subsidize the product in order to allow its survival? Does it allow it to go bankrupt? Does it protect it with tariffs against competing foreign made products? Or can the product be adapted to make it competitive?

We are in the process of constructing a generic model of competition between an established and a new technology that will be usable for exploring questions such as those described in the last two paragraphs. Mathematically it is a nonlinear system with seven state variables. Each technological production system is characterized by three state variables--production capacity inventories of output and cumulative output. The feedback structure linking these variables is shown in Figure 5.

This model, TECH1, as we call it, is presently a conceptual tool, which can be used to relate the attributes of a technology to the means appropriate to its promotion. It proves to be very sensitive to two things: the steepness of the curve relating cumulative output to technological efficiency, i.e., the learning curve, and the relative consumer attractiveness of the products of the two technologies. These factors are critical because they strongly affect the two positive feedback loops shown in Figure 6.

The role of the learning curve should be quite apparent. Where learning is fast the left hand loop in Figure 6 will give a rapid boost to the new technology, which will saturate as it moves toward full efficiency. Clearly the learning curve becomes much

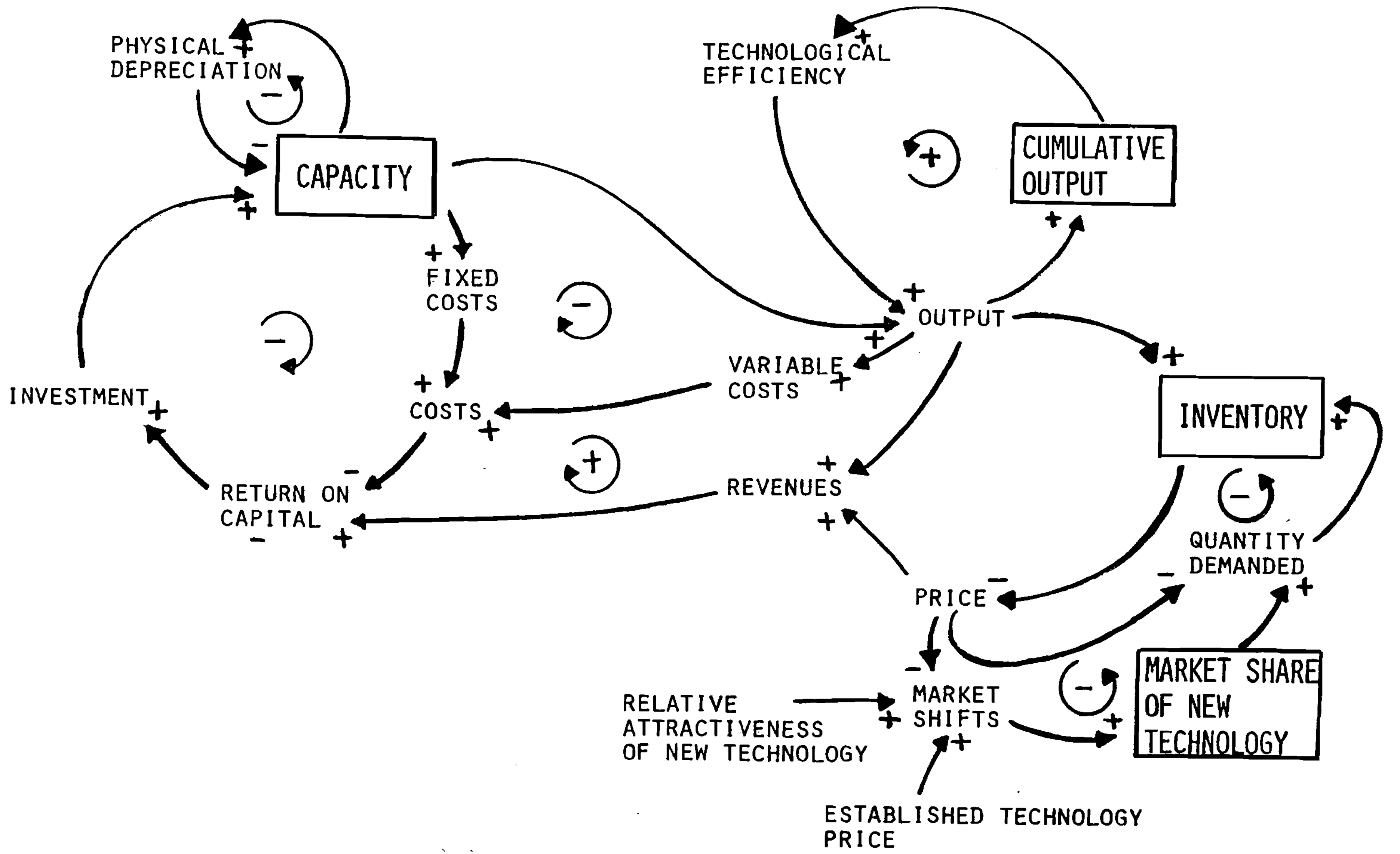

Figure 5. Main Feedback Structure of the New Technology Portion of TECH1.

(−) designates a negative feedback loop.

(+) designates a positive loop.

Rectangles indicate state variables.

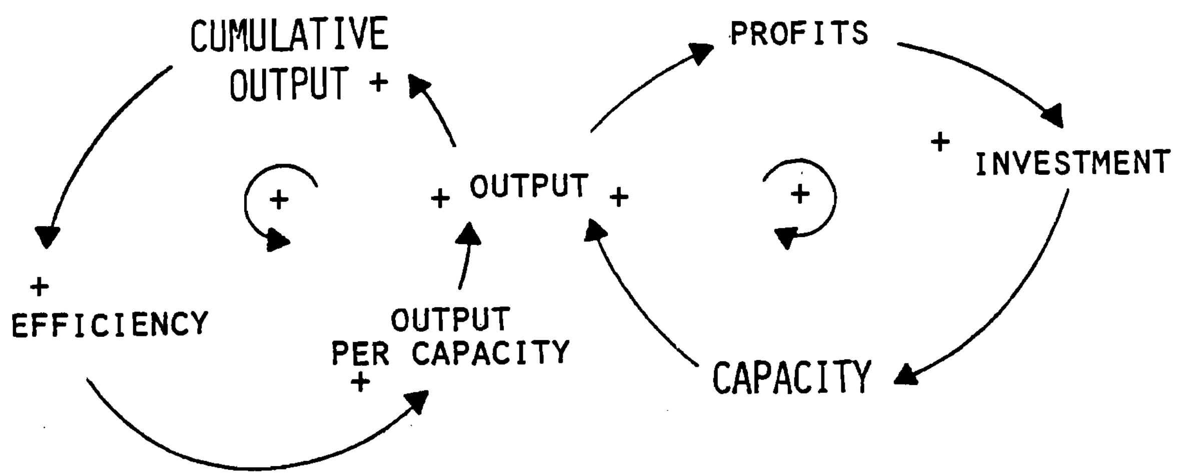

Figure 6. Positive feedback boosting a technology's growth.

steeper as one moves from low (a) to high (d) technologies. The model, therefore, shows that high technologies will have a much more difficult time taking off than lower technologies. Indeed, they may be unable to take off without considerable support and protection in the long period before they attain high technological efficiency.

The role of consumer preference is less immediately obvious. Basically when consumers favour the new technology it tends to find itself in the profitable situation of being unable to expand quite fast enough to meet demand; this means product inventories are chronically low and prices and profits high. Profits stimulate investment and growth takes off.

With respect to developing countries, the system's sensitivity to consumer preference contains several lessons. With good planning it could be used to give domestic producers a competitive advantage over foreign multinationals. Domestic producers are in a much better position to understand and respond to the needs of a nation's population than are multinationals if they can be induced to be sensitive to local tastes and preferences (which unfortunately has often not been the case) they should be able to gain market share through appeal to local tastes even where they may have difficulty in competing purely on price terms.

In more general terms, it suggests that a strategy of building pride in local products may be essential to economic growth in the developing countries. Multinationals <u>do</u> understand the importance of marketing and <u>do</u> use advertisement deliberately to create market preferences for their products. If local products are not of poor quality a sense of nationalism, and of pride in self-reliance can undermine multinational marketing attempts. If the population understands that by supporting local manufacturers it is, in the long run, elevating its own standard of living and power of self determination, and if it bases its purchasing habits on that understanding, technological transformations of all sorts will tend to become self-perpetuating and will require much less government support.

Although TECH1 is still in the early stages of development, and we have yet much to learn from it, the above should demonstrate that models can be used as tools to organize, expand and synthesize our ideas about appropriate technology.

Conclusions

Development is a complex social process which rests in large part upon the internal innovative capabilities of a society. It is critical that the developing countries gain effective control over the three primary factors influencing the initiation and successful implementation of technical innovation: the market, production, and technical factors. Demand factors are critical for the success or failure of new technologies. Therefore the developing countries must think about how to create and identify demand from the point of view of national needs, as well as how to connect demand with technological feasibilities. This requires a concept of the development of the national technological basis.

Innovation is not a single action but a total process of interrelated sub-processes. It is not just the conception of new ideas, not the invention of a new device, nor the development of a new market. Innovative capability of society can only be improved if government policy tries to stimulate all stages of the innovative process: the invention stage, the technical realization stage and the commercialization stage. It is not possible to have appropriate technology without mastering the interlinkages between these different stages.

The question "What is appropriate technology?" cannot be answered from the standpoint of a single technology. The same technology may or may not be appropriate, depending on how it is integrated into the national technological basis and what is its influence on the national development. A well integrated national technology must include mutually reinforcing development of different types and levels of technologies. Labor intensive, capital intensive, small scale, large scale, low cost, traditional and sophisticated. The problem is to combine these different technologies in a way that efficiently meets national needs. Currently, we find that the developed countries typically produce and export technologies oriented towards filling their own needs and goals. A "gap" exists for technologies, which are not only highly efficient in concrete processes, which can effectively use human and national resources in the developing countries, but which can also easily be adapted to the specific conditions of developing countries. Helping the developing countries to create such technologies and to fuse them with advanced technologies should be a high priority matter in international cooperation and international technology transfer.

Can models help? Thinking about the existing models of developing countries and the nature of the problem of innovation in these countries we must concede that mathematical models can play only a limited role. The most important questions--identification of social needs and matching them with technical possibilities--cannot be reduced to precise mathematical form. Nor can mathematical models be of great use in understanding the interplay of social-cultural factors with technological factors--because both sides of the formula are extremely difficult to define precisely or to quantify. Therefore we must leave the larger strategic questions to verbal analysis.

Mathematical models can, however, be helpful in working out tactical questions. Accounting-type models can be of great help in keeping track of the innovation process, avoiding double counting and helping to assure that planners don't leave out critical budgetary factors. Dynamic models can also be of assistance by helping planners keep track of slower moving, underlying trends such as the build-up of capital and the gradual shifting of population characteristics and consumer taste.

In our work at IIASA we are developing a general model of the interplay of market forces, the learning curve and capacity and capital accumulation which could be adapted to help examine ways in which developing countries could increase their success in substituting indigenously owned and controlled technical structures for foreign controlled ones.

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